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OFF-ROAD DETECTION FOR IMPROVING TIRE PRESSURE LOSS DETECTION

Background Information

The invention relates to a method and a device for monitoring the tire condition of a vehicle having the features of the independent claims.

Systems for detecting a tire condition are known from the related art. Besides the direct determination of the air pressure of a tire, rotational speeds of the wheels can be used to determine changes in tire pressure.

Changes in the rotational speeds of individual wheels can be determined and used for indicating the change in the condition of the tires. Systems that indicate the tire condition under certain operational conditions (unbraked, unaccelerated straight-ahead driving) are introduced in DE 36 10 116 A and DE 32 36 520 C. Also proposed in these documents is normalization of the rotational speeds to the particular vehicle speed.

Using differences between the rotational speeds of individual wheels for recognizing tire condition is known from EP 0 291 217 B1.

DE 199 44 391 A1 describes the adaptation of a calibration value used for monitoring tire pressure. Here, recalibration of the tire pressure system is performed based on a changed operational condition of the wheel, the old value being overwritten.

Advantages of the Invention

As mentioned above, the invention describes a method and a device for monitoring the tire condition of a vehicle, the tire pressure on the wheels of the vehicle, in particular, being monitored. The core of the present invention lies in the fact that monitoring of the tire condition depends on the condition of the surface on which the vehicle is traveling. According to the present invention, this results in an improved pressure loss display based on the transmission of force between the vehicle wheels and the road surface which changes to a lesser or higher degree when traveling under constantly changing road friction values on the wheels.

One exemplary embodiment provides for the monitoring to take place in at least two different, independent monitoring modes depending on the driving surface. The different monitoring modes differ from one another in that each uses a separate calibration data set as a reference data set.

One embodiment feature of the present invention relates to the determination of the condition of the driving surface using a signal representing the transmission of force between the wheels of the vehicle and the driving surface. In particular, this signal involves the transmission of force between the wheels of the vehicle and the driving surface to take place via time averaging in order to equalize short-term disturbances or short-term changes in the condition of the driving surface.

Another embodiment feature of the present invention relates to the determination of the different calibration data sets that are used as reference data sets for monitoring the tire condition. The calibration data sets are determined here as a function of a signal representing the transmission of force between the wheels of the vehicle and the driving surface,

and/or a command initiated by the driver of the vehicle. In particular, the signal may be generated by a system outside of the actual monitoring device according to the present invention. It may also be possible for the driver to start the initialization of the particular applicable calibration data set by manually actuating a switch, for instance.

For the purpose of monitoring the tire condition, one embodiment of the present invention compares the wheel dynamics variable representing the wheel dynamics with one another at different points in time. In particular, the wheel dynamics variable is to be represented by the wheel rotational speed and thus by the rotational speed of the wheels. For this reason, the wheel rotational speeds are determined at regular intervals for determining the velocity of the wheels.

In one embodiment of the present invention, the wheel dynamics variable representing the tire condition is now to be determined by forming a difference between the wheel rotational speeds of at least two wheels. In particular, the differences between the rotational speeds of the wheels on one axle and/or of diagonally situated wheels are to be formed. In another embodiment of the present invention, the wheel rotational speeds on one axle may initially be added up.

In a further embodiment of the present invention, the difference between the sum of the wheel rotational speeds of the wheels on the front axle and the sum of the wheel rotational speeds of the wheels on the rear axle may be formed. The resulting difference is subsequently normalized to the vehicle speed. In another, comparable difference-forming method, first the sum of the wheel rotational speeds of the wheels on the right side is formed, and the sum of the wheel rotational speeds of the wheels on the left side is subtracted from the former. The resulting difference may then also be normalized to the vehicle speed.

The difference is formed by forming the wheel rotational speed differences between the front and the rear wheels, as well as between the wheels on the right and the left side, normalized in each case to the vehicle speed.

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In a further embodiment of the present invention, the calibration data sets are determined and stored on the basis of the calculated differences between the wheel rotational speeds, as a function of the condition of the driving surface or the associated transmission of force between the wheels of the vehicle and the driving surface and/or a command initiated by the driver of the vehicle. In particular, the driver may initiate the determination and storage of the calibration data set - by manually actuating a switch for example - if he detects, for instance, that he is about to drive off-road.

A particularly advantageous refinement of the present invention is a method and a device for monitoring the tire condition, where the currently calculated wheel rotational speed differences are compared with the applicable, driving surface-dependent calibration data set. Should the current wheel rotational speed differences lie outside of a predefined range in relation to the applicable calibration data set, the monitor detects a malfunction. If a malfunction occurs, the driver of the vehicle may be informed of the change in the tire condition, in particular via an optical or acoustic display.

In another advantageous embodiment of the present invention, the occurrence of a malfunction is used to modify a brake system in the vehicle in such a way that critical driving conditions are avoided and at least the tire is damaged to a lesser degree. The functions of other vehicle systems, as well, are modifiable in response to a malfunction. For instance, in the event of a detected malfunction such as low tire pressure, the speed of the vehicle may be restricted.

In one particular variant of the present invention, the tire condition is to be monitored via the air pressure in a tire and/or the wear condition of a tire.

5 Another advantage of the present invention explained in the main claim and the subclaims lies in the fact that the method or the device is suited in particular for use in an all-wheel drive vehicle, since all-wheel drive vehicles are regularly used for driving on surfaces of varying conditions.

10 Additional advantageous embodiments of the inventions are found in the subclaims.

Drawing

15 Figure 1 shows a schematic view of the recording of the performance variables for calibrating and monitoring the tire condition of the vehicle, as well as the relaying of the malfunction information. Figure 2 shows, in the form of a flow
20 chart, the initialization of the system and the storing of the calibration data sets for the two monitoring modes. The flow chart in Figure 3 shows a preferred monitoring of the tire condition in the two monitoring modes.

25 Description of the Exemplary Embodiment

Figure 1 shows an exemplary embodiment for monitoring the tire condition of a vehicle, to be understood, in particular, as the monitoring of the tire pressure based on the measured
30 speeds of the vehicle wheels. Block 10 contains monitoring unit 20 and memory 50.

Monitoring unit 20 receives speed signals representing the wheel velocities of the vehicle wheels. In order to simplify
35 the layout, Figure 1 shows only the speed signals of the left wheel v_{FL} (22) and the right wheel v_{FR} (24) on the front axle and

the left wheel v_{RL} (26) and the right wheel v_{RR} (28) on the rear axle. An extension to several axles, as well as additional wheels per axle, is easy, however. In addition to the speed signals of the wheels, the overall speed of the vehicle is read in via speed signal v_{car} (30). Furthermore, in block 20, the state of an initialization is interrogated via an F_i flag (40) and the state of the condition of the driving surface is interrogated via an F_{off} flag (45), the set F_i flag = 1 corresponding to the request for performing an initialization of the system for example by the driver of the vehicle. However, it may also be possible to determine the condition of the driving surface independently of the driver, and to set the F_i flag as a function of the driving surface condition thus determined.

The condition of the driving surface plays an important role in the transmission of force between the wheels of the vehicle and the driving surface. When driving on a road such as a paved surface having high and uniform transmission of force between the wheels of the vehicle and the driving surface, the transmission of force has a normal value under these "normal conditions." Should the transmission of force decrease in relation to the normal value - such as during off-road driving - below a threshold value, the F_{off} flag = 1 is set by an external system situated outside block 10. It may also be possible for the driver of the vehicle to set the flag manually. A set F_{off} flag corresponds to driving under off-road conditions distinct from driving under "normal conditions."

The calibration data sets generated after initialization may be stored in block 50 as reference values for monitoring the tire condition.

Should a malfunction of the tire condition be detected in block 20, this information may be relayed to the driver either acoustically or optically via an appropriate display (90). In

addition, the malfunction of the tire condition is also usable for intervening in the vehicle dynamics such as in an ESP-system (80) for improving the driving stability.

5 Figure 2 shows an exemplary embodiment of the initialization of the system for monitoring the tire condition, and the tire pressure in particular. In step 100, flag F_i is interrogated at regular intervals. If a set flag F_i is detected, the initialization of the system is started via the generation of
10 a calibration data set. Otherwise the program is terminated until the next start. In step 110, the speed signals v_{FL} , v_{FR} , v_{RL} , v_{RR} of the individual wheels are read in, as well as the vehicle speed via v_{car} . For instance, the vehicle speed is determinable from the averaged wheel rotational speeds in a
15 generally known manner. The differences in the wheel speeds are formed via these speed signals.

In this exemplary embodiment, the wheel velocity differences are formed by forming the difference between the sum of the
20 wheel rotational speeds of the wheels on the front axle and the sum of the wheel rotational speeds of the wheels on the rear axle, normalized to the vehicle speed according to

$$\Delta V_A := \{ (v_{FL} + v_{FR}) - (v_{RL} + v_{RR}) \} / v_{car}$$

25 The difference may also be formed by deducting the sum of the wheel rotational speeds of the wheels on the left side from the sum of the wheel rotational speeds of the wheels on the right side. The resulting difference may then also be
30 normalized to the vehicle speed according to

$$\Delta V_D := \{ (v_{FL} + v_{RR}) - (v_{FR} + v_{RL}) \} / v_{car}$$

Furthermore, any other method of forming the difference
35 between the wheel velocities is conceivable.

If the system detects - via set flag F_{off} in step 130 - that the vehicle is traveling with reduced transmission of force between the vehicle wheels and the driving surface, the determined differences in wheel speeds are stored as calibration data set II (150) in monitoring mode II. If the vehicle is traveling under "normal conditions," i.e., flag F_{off} is not set, the determined differences in wheel velocities are stored as calibration data set I (140) in monitoring mode I.

Figure 3 shows an exemplary embodiment of the detection of a malfunction in monitoring the tire condition, in particular the tire pressure of a vehicle. The sketched program is started at predefined cycles throughout the entire operation. The flow chart essentially compares the actually determined instantaneous differences in wheel velocities with the calibration data sets in the two monitoring modes.

In step 200, speed signals v_{FL} , v_{FR} , v_{RL} , v_{RR} and v_{car} are read in. Using these speed signals, the differences in wheel velocities are formed in step 210 according to step 120 in Figure 2. If the system detects that the vehicle is traveling with reduced transmission of force between the wheels of the vehicle and the driving surface via set flag F_{off} in step 220, it compares the differences in wheel velocities determined in step 210 with calibration data set II in step 270. Should the deviation of the two values exceed a predefinable amount, a malfunction, in particular a tire pressure loss, is detected in step 280 and brought to the attention of the driver via an acoustical or optical display (90). If the deviation lies within the predefined limits, the program is terminated and restarted during the next cycle.

If the system detects a transmission of force between the wheels of the vehicle and the driving surface under "normal conditions," via unset flag F_{off} in step 220, it compares the differences in wheel velocities determined in step 210 with

calibration data set I in step 240. Should the deviation of the two values exceed a predefinable amount, a malfunction, in particular a tire pressure loss, is detected in step 250 and brought to the attention of the driver via an acoustical or optical display (90). If the deviation lies within the predefined limits, the program is terminated and restarted during the next cycle.